1. Title of the invention

Information Recording Medium

2. Claims

(1) An information recording medium comprising a substrate and a magnetic layer which is formed by laminating a recording layer and a reproducing layer, the recording layer and the reproducing layer are each composed of an magnetic alloy and have an easy axis of magnetization in a direction perpendicular to their respective surfaces, wherein:
recorded information is deleted by reversing the magnetization of the magnetic layer by heat produced by optical beam irradiation;
information is reproduced by irradiating the magnetic layer with an optical beam; and
the recording layer and the magnetic layer are each formed of an alloy having a composition expressed by $Mn_{1-x-y}A_xD_y$ (A represents at least one element selected from Al, Ga, In, Sb, Bi, Te, Se, Sn, Pb, and As, D represents at least one element selected from Ge, Si, C, B, P, Cu, Zn, Ti, and Pt, and x and y are within a range of $0.1 \leqq x \leqq 0.6$ and $0.1 \leqq y \leqq 0.6$ respectively), the recording layer being crystalline, the reproducing layer being mainly amorphous.

(2) An information recording medium according to claim 1, wherein the reproducing layer is formed by dispersing a crystalline alloy composed of a fine crystalline grain having a crystal grain size of equal to or less than 0.1 μm in an amorphous alloy.

(3) An information recording medium according to claim 2, wherein the crystalline alloy dispersed in the reproducing layer is equal to or less than 30 vol.%.

(4) An information recording medium according to any one of claims 1 to 3, wherein the recording layer and the

reproducing layer each have a columnar crystal with a diameter of equal to or less than 0.1 μm vertically formed with respect to their surfaces.

(5) An information recording medium according to any one of claims 1 to 4, wherein the crystal grain of the recording layer is equal to or less than 0.1 μm in diameter and is oriented so that an easy axis of magnetization is in the direction perpendicular to the surface of the recording layer.

(6) An information recording medium according to any one of claims 1 to 5, wherein the recording layer is formed on a substrate kept at equal to or more than 100℃ to equal to or less than 500℃.

3. Detailed Description of the Invention

(Effects)

In the present invention, the recording layer and the reproducing layer are formed of crystalline material and amorphous material respectively, that have the above-described compositions. By forming the recording layer and the reproducing layer with such compositions, it is possible to obtain favorable recording/reproducing characteristics. Since the amorphous alloy having the composition $Mn_{1-x-y}A_xD_y$ that is applied to the reproducing layer has an excellent magneto-optical effect such as a large Kerr rotation angle, C/N of the reproducing signal is high, displaying excellent reproducing characteristics. Also, the crystalline alloy of the same composition that is applied to the recording layer has a high coercive force, displaying excellent recording characteristics. In addition, those compositions have high stability.

(Embodiment)

Hereafter, an embodiment of the present invention will be described in detail with reference to the attached drawings.

Fig.1 is a cross-sectional view showing an information recording medium according to the embodiment. A substrate 11 is formed of a transparent material that shows little change with the lapse of time. For the material, a transparent resin material such as polymethylmethacrylate, with which a pre-groove is easily formed and safety is high while high-speed rotation, polycarbonate, or epoxy is preferable. If there is a possibility that the substrate can be heated to a high temperature during manufacturing or use, transparent glass, ceramics, and the like may be used. On the substrate 11, a first protective layer 12, a reproducing layer 13, a recording layer 14, a second protective layer 15 and a third protective layer 16 are laminated in the mentioned order, with a magnetic layer 20 being formed of the first protective layer 12, the reproducing layer 13, and the recording layer 14. The first protective layer 12 and the second protective layer 15 are transparent, are composed of, for example, an oxide such as SiO, SiO_2, TiO_2, SnO_2 and Bi_2O_3, or a nitride such as Si_3N_4 and AlN, and have functions to protect the reproducing layer 13 and the recording layer 14 and to enhance the magneto-optical effect. The third protective layer 16 is composed of a high molecule and has a function to protect the reproducing layer 13 and the recording layer 14 from oxidation. Note that although it is preferable to provide the protective layers 12, 15, 16, the protective layers may not be provided.

The reproducing layer 13 is formed on the protective layer 12, for example, and is composed of an amorphous alloy having a composition $Mn_{1-x-y}A_xD_y$. A is at least one element selected from Al, Ga, In, Sb, Bi, Te, Se, Sn, Pb, and As, appropriate amount of which increase the magneto-optical characteristics such as the Kerr rotation angle when added. When the content of the element(s), that is, the value of x is less than 0.1, the effect of increasing the magneto-optical characteristics is small, and when the value of x is more than 0.6, the Curie temperature decreases to or less than the room temperature,

thereby decreasing the magneto-optical effect and thermal stability. The value of x, therefore, is set in a range of $0.1 \leqq x \leqq 0.6$. D is at least one element selected from Ge, Si, C, B, P, Cu, Zn, Ti, and Pt, and has the effects of stabilizing the amorphous state and increasing the C/N ratio during reproducing. When the content of the element(s), that is, the value of y is less than 0.1, the C/N ratio of the reproducing signal decreases because the reproducing layer is easily crystallized due to an increased temperature during recording/reproducing, and when the value of y is greater than 0.6, the magneto-optical effect decreases. The value of y, therefore, is set in a range of $0.1 \leqq y \leqq 0.6$. By forming the reproducing layer 13 with an amorphous alloy of such a composition, it is possible to obtain favorable magneto-optical characteristics such as a large Kerr rotation angle. As a result, it is possible to obtain favorable characteristics, or a high C/N ratio, as a reproducing layer. It is also possible to have the reproducing layer 13 in a state where a fine grain of crystalline alloy is dispersed in an amorphous alloy. In this case, when the fine grain of crystalline alloy is equal to or less than $0.1\mu m$ in crystal grain size and the content of the crystalline alloy is equal to or less than 30 vol.%, it is possible to obtain magneto-optical characteristics equivalent to or better than those obtained using amorphous alloy only. In addition, when the fine crystalline grain is a columnar crystal whose axial direction matches the easy axis of magnetization of the reproducing layer 13, it is possible to further improve the reproducing characteristics.

The recording layer 14 is formed on the reproducing layer 13, for example, has a composition $Mn_{1-x-y}A_xD_y$ in the same way as the reproducing layer 13, and is formed of a crystalline alloy. Here, A and D are each at least one element selected from similar elements to those with the reproducing layer 13. By adding an appropriate amount of A and D, it is possible to increase the crystal magnetic anisotropy (K), which makes it possible to

obtain a high coercive force. In this case, when the respective values of x and y are less than 0.1, the value of K is small and recording reliability is low. Also, when the respective values of x and y are more than 0.6, the Curie temperature decreases and so does the value of K. Accordingly, the respective values of x and y are set in the same range as with the reproducing layer. By forming the recording layer 14 with a crystalline alloy having such a composition, it is possible to improve magnetic characteristics such as coercive force. As a result, it is possible to obtain favorable recording characteristics. In addition, the substrate 11 should preferably be set at a temperature of 100℃ to 500℃ when the recording layer 14 is formed. By doing so, it is possible to increase the coercive force, which makes it possible to increase the squareness ratio of a hysteresis loop in a magnetization curve. When the substrate is a heat resistance glass, ceramics or single crystal substrate, it is possible to obtain similar characteristics even when the temperature of the substrate is 500℃ to 700℃. As for the recording layer 14, it is possible to obtain equivalent recording characteristics or high coercive force by first forming an amorphous alloy layer with the same composition, then irradiating the amorphous alloy layer with a laser beam and the like to heat the amorphous layer, and crystallizing the amorphous layer to form the recording layer, without heating the substrate 11 as described above. The Curie temperature of the crystal alloy used to form the recording layer 14 should preferably be 50℃ to 250℃. By selecting component elements of A and B to be added as appropriate, it is possible to obtain a desired Curie temperature. Also, the coercive force should preferably be 1 or equal to or more than $2kO_C$. By selecting component elements of A and B as appropriate or by adjusting the substrate temperature, thermal processing temperature, or the crystallization temperature, it is possible to obtain a desired coercive force.

The crystalline grain of the crystalline alloy for forming the

recording layer 14 should preferably: be equal to or less than 0.1μm in crystal grain size; be oriented so that the easy axis of magnetization of the recording layer 14 is perpendicular to the surface thereof; be in a columnar crystal with a diameter equal to or less than 0.1μm; and have its axial direction match the easy axis of magnetization. By doing so, recording characteristics are further improved and it is possible to increase the C/N ratio of the reproducing signal during reproducing.

In the information recording medium formed as described above, when irradiating the magnetic layer 20 with a recording laser beam from the substrate 11 side, the magnetization of irradiated positions in the reproducing layer 13 and the recording layer 14 are reversed, thereby recording information. In this case, the recording layer 14 has a large coercive force and the like as described above, therefore displays favorable recording characteristics as the whole magnetic layer. Also, when irradiating the magnetic layer 20 on which information has been recorded with a laser beam for reproducing, the reproducing layer 13 has a large polar Kerr rotation angle, thereby displaying favorable reproducing characteristics as the whole magnetic layer.

As described above, by constructing the magnetic layer 20 by laminating the reproducing layer 13 and the recording layer 14, it is possible to obtain favorable recording/reproducing characteristics.

Note that in this embodiment, although the recording layer 14 is formed on the reproducing layer 13, the laminating order may be reversed. Also, it is advisable to set the thickness of the reproducing layer at about 100Å to 500Å, and the thickness of the recording layer at about not less than 100Å. The compositions of the reproducing layer and the recording layer may be the same or totally different so long as the reproducing

layer is composed of an amorphous alloy film with a large magneto-optical effect and the recording layer is composed of a crystalline alloy film with a large coercive force, a high squareness ratio of a hysteresis loop in a magnetization curve, and an appropriate Curie temperature.

The reproducing layer 13 and the recording layer 14 described above can be created by a film forming method ordinarily used such as RF sputtering, DC sputtering, magnetron sputtering, ion beam sputtering, electron beam vapor deposition, cluster beam, molecular beam epitaxy, CVD. In this case, the substrate temperature of the amorphous alloy film should preferably be set at equal to or less than 100℃, and the temperature of the crystalline alloy film at 100℃ to 500℃. Note that when forming the recording layer 14 of the crystalline alloy film by raising the substrate temperature, the reproducing film 13 of the amorphous alloy film should preferably be formed on the recording layer after the recording layer is formed. When forming the recording layer 14 on the reproducing layer after the reproducing layer 13 is formed, the reproducing layer and the recording layer should preferably be formed in an amorphous state without raising the substrate temperature by irradiating only the recording layer 14 portions with a laser beam and the like to heat and crystallize the recording layer 14.

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Next, an example of a test will be described with regards to an information recording medium according to the embodiment that was actually created and tested. In this example, the layer was constructed in the same way as shown in Fig.1. A polymethylmethacrylate was used as a substrate 11, on which were formed an Si_3N_4 protective layer 12, an MnAlGe amorphous alloy reproducing layer 13, an MnCuBi multicrystalline alloy recording layer 14, a Si_3N_4 protective layer 15, and a high molecular protective layer 16 in the mentioned order with a

magnetic layer 20 being formed by the protective layer 12, the reproducing layer 13, and the recording layer 14 to create an optical thermomagnetic recording type information recording medium sample. All of the layers except for the high molecule protective layer 16 were formed by the sputtering apparatus described above. Of the magnetic layer 20, the reproducing layer 13 was formed with a thickness of 500Å using a composite target having a desired composition, which was formed by disposing a predetermined number of thin plate-shaped Al, Ge tips on an Mn plate with a diameter of 5 inch after forming the Si_3N_4 protective layer 12 with a thickness of 1000Å. When the X-ray diffraction pattern of the reproducing layer 13 formed as described above was examined, some crystalline diffracted rays were observed, but most of the diffracted rays were amorphous. When the composition of the reproducing layer was analyzed, it was confirmed that the composition was $Mn_{0.4}Al_{0.3}Ce_{0.3}$. Further, when the magnetic Kerr hysteresis loop was measured using a polarization device in a magnetic field, it was confirmed that an easy axis of magnetization was present in the layer in the direction perpendicular to the layer surface, that the value of the polar Kerr rotation angle was as large as 1.0° at a measurement wavelength (λ) of 633nm, and that the coercive force was $400O_e$ at 25℃. Also, when the crystallization temperature was measured by a differential scanning calorimetry (DSC) or a four-terminal method, the crystallization temperature was 470℃ and it was confirmed that the thermal stability was high.

The recording layer 14 was formed with a thickness of 1000Å using a composite target having a desired composition, which was formed by disposing a predetermined number of thin plate-shaped Cu, Bi tips on an Mn plate with a diameter of 5 inch after the reproducing layer was formed. From an examination of the X-ray diffraction pattern of the recording layer 14 formed as described above, it was confirmed that the recording layer was amorphous. Also, when the composition of the recording layer 14 was analyzed, the composition was $Mn_{0.27}Cu_{0.36}Bi_{0.37}$.

When the X-ray diffraction pattern of the recording layer 14 was examined after irradiating the recording layer 14 with a laser beam to heat the layer, the layer had a cubic structure $Mn_3Cu_4Bi_4$ and was oriented so that the layer surface became the (222) plane. Also, when a cross-section of the recording layer 14 was observed by a scanning electron microscope (SEM), the cross-section was columnar crystals each with a diameter of about 400Å. ...

Next, test results will be described with regards to the reproducing layer 13 and the recording layer 14 with various compositions different from the above-described composition.

Table 1 shows compositions of the reproducing layer 13, polar Kerr rotation angles Φx (deg), and crystallization temperatures Tx (℃). In the table, Samples are within the claimed range of the present invention and Comparative Examples are beyond the claimed range of the present invention.

According to Table 1, all the compositions of Samples were in the state of amorphous, the polar Kerr rotation angles were equal to or more than 0.7° showing favorable magneto-optical characteristics, the crystallization temperatures were equal to or more than 420℃ showing favorable reproducing characteristics. On the contrary, with the composition $Tb_{0.24}Co_{0.76}$ in Comparative Example 1, the crystallization temperature was as high as 520℃ but the polar Kerr rotation angle was as small as 0.25° . With the crystalline $Mn_{0.33}Al_{0.34}Ge_{0.33}$ in Comparative Example 2, the Kerr rotation angle was as extremely small as 0.02° . In other words, it was confirmed that the reproducing characteristics were inferior in the Comparative Examples.

Table 2 shows compositions of the recording layer 14, coercive forces (kO_e), and Curie temperatures Tc (℃) with regards to Samples and Comparative Examples in the similar way to Table

1.

According to Table 2, all the compositions of Samples were crystalline, the coercive forces were as high as equal to or more than 1.5 kO_C, the Curie temperatures were equal to or more than 150℃, and it was confirmed that favorable characteristics were shown for the recording layer. On the contrary, both Comparative Examples 1 and 2 were amorphous with small coercive forces and low Curie temperatures, and it was confirmed that recording characteristics were inferior.
As described above, it was confirmed that it is possible to obtain an optical thermomagnetic recording type information recording medium with excellent recording/reproducing characteristics by forming the reproducing layer and the recording layer with an amorphous alloy and a crystalline alloy respectively within the range of compositions as shown in the Samples. ...